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STATUS OF LOBSTER STOCKS IN THE NORTHWESTERN HAWAIIAN ISLANDS, 1990

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ABSTRACT

In 1990, fishing effort in the lobster fishery in the Northwestern Hawaiian Islands (NWHI) was almost 1.2 million trap-hauls, resulting in landings of about 184,000 slipper lobster, *Scyllarides squammosus*, and 591,000 spiny lobster, *Panulirus marginatus,* for a catch per unit effort (CPUE) of 0.66 lobster/trap-haul. This is the lowest annual CPUE since the inception of the fishery in the late 1970s. Analyses of commercial logbooks and research sampling data conclude the following:

(1) Low recruitment to the fishery was observed at Maro Reef and northwestern banks, resulting in a decline in CPUE. Thus, most fishing effort was directed at Necker Island and Gardner Pinnacles, resulting in those populations being fished down.

(2) The spawning biomass index based on CPUE estimates the 1990 level is 22% of the pre-fishery level, an indication that 1.2 million trap-hauls may have been excessive since recruitment to the fishery was low. It should be remembered that the 1990 spawning biomass is the lowest yet observed and the recruitment to the fishery from the 1990 spawning biomass will not be observed until 1993.

(3) As of November 1990, there was no indication that recruitment at Maro Reef and other northwestern banks has improved.

(4) While a maximum sustainable yield (MSY) of 1 million lobsters with 1 million trap-hauls still appears appropriate, 1990 has shown that this is a long-term average, and considerable year-to-year variation can occur. To protect the population in poor years, management must be able to regulate annual catch or effort.

(5) Two actions can protect the current spawning biomass and promote the recovery of the annual CPUE to the 0.9-1.0 range in 1991: (a) close the fishery from January through August to protect the spawning population both before and during the spawning period; and (b) limit annual fishing effort to 200,000 trap-hauls, which can be adjusted upward to 400,000 trap-hauls if recruitment to the fishery at Maro Reef appears normal.

INTRODUCTION

This is the sixth annual report on the status of lobster stocks in the NWHI (see, for example, Polovina 1990). This report uses research data as well as catch and effort data from the logbooks of commercial fishermen to describe spatial and temporal variation in abundance of slipper lobster, *Scyllarides squammosus*, and spiny lobster, *Panulirus marginatus*, and to estimate optimum exploitation levels.

MODELS

Two mathematical models are fit to the catch and effort data to estimate biological parameters needed for stock assessment. The first is the Fox surplus production model which expresses catch (C) as a function of fishing effort (E), catchability (q), unexploited biomass (K), and the intrinsic rate of population increase (r):

$$C = qKEe^{-qE/r}.$$

The relationship between catch and effort described by this model is an equilibrium relationship. Given the rapid annual changes in effort in the lobster fishery, it is not appropriate to fit this model to annual catch and effort data. Instead, the dynamic Fox production model, derived in Clarke et al. (in preparation), should be used. The dynamic model expresses annual CPUE in year $t+1$ as a function of CPUE in the previous year and effort in years t and $t+1$ as

$$ln(CPUE_{t+1}) = A + B*ln(CPUE_t) + C*(E_t + E_{t+1});$$

where A, B, and C are constants which are functions of parameters q, K, and r.

The second model, termed the CPUE model, expresses monthly CPUE ($CPUE_t$) as a function of CPUE in the same month of the previous year $CPUE_{t-12}$, cumulative effort over the 12-month period from month $t-11$ to t (E_t), annual instantaneous natural mortality (M), annual recruitment to the fishery (R), and catchability (q) as

$$CPUE_t = Re^{-M/2\ -qE_t/2} + CPUE_{t-12}e^{-M\ -\ qE_t}.$$

The CPUE model differs from the production model approach in that it assumes constant recruitment; therefore, the differences between the model and data may identify monthly changes in recruitment, catchability, or both. This model also estimates natural mortality which is needed for the spawning potential ratio estimation.

CATCH AND EFFORT DATA

Species-specific CPUE cannot be computed because commercial logbooks report only total lobster fishing effort rather than distinguishing between fishing effort targeting slipper and spiny lobsters. In 1990, effort was almost 1.2 million trap-hauls, a 10% increase over 1989, while total CPUE for both species was 0.66 lobster/trap-haul, a 39% decrease from 1989 (Table 1). Since 1988, the landings in the fishery have been dominated by spiny lobster, and this trend continued in 1990 when spiny lobster accounted for 76% of the landings (Table 1).

The observed shift in fishing effort from Maro Reef to Necker Island and Gardner Pinnacles in 1989 continued in 1990, resulting in a dramatic decrease in catch and effort from Maro Reef and an equally dramatic increase from Necker Island and Gardner Pinnacles (Fig. 1). The dynamic Fox production model fit to the 1983-90 catch and effort data for the entire NWHI estimates $q = 9 \times 10^{-7}$, an MSY of 900,000 lobsters with fishing effort of 740,000 trap-hauls and resulting CPUE of 1.22 lobster/trap-haul (Fig. 1). By comparison, the same model with 1983-89 data estimated MSY at 1 million lobsters with fishing effort of 1 million trap-hauls and a CPUE of 1.0 (Polovina 1990). As discussed later, there are indications that 1990 recruitment was particularly low, because of factors other than fishing effort. Hence, the MSY estimate of 1 million lobsters with 1 million trap-hauls may be more representative of the long-term level.

Monthly catch and effort data from logbooks show that CPUE has remained low since the last quarter of 1989 (Fig. 2). The CPUE model estimates $q = 1.0 \times 10^{-6}$ and $M = 0.7$/year and 1990 fishing mortality as 1.2/year. The monthly CPUE model shows that the general decline in CPUE since 1984 can be explained by fishing effort, but there is considerable within- and between-year variation around the model's CPUE estimates. The differences between the actual monthly CPUE and the model's CPUE estimate are called the residuals in Figure 2 and represent monthly changes in catchability, recruitment to the fishery, or both. The monthly CPUE remains below the level estimated by the model from late 1989 through 1990. The CPUE data do not indicate whether this decline was due to a change in catchability, to cold water (as probably was the case in 1987), or to a decline in recruitment. However, from the size-frequency data presented in the next section, recruitment to the fishery apparently declined in 1990.

Although the dynamic Fox and the CPUE models are based on different assumptions, estimates of their common parameter (q) are very similar, and their estimated equilibrium catch and effort curves also are similar (Fig. 1) up to an effort level of 1 million trap-hauls when the difference in stock-recruitment assumptions becomes important.

SIZE-FREQUENCY DATA

The NOAA ship, *Townsend Cromwell*, conducted research trapping at Necker Island and Maro Reef from 23 June to 19 July 1990. This represents the fourth year of systematic sampling at the same sites and with the same type of traps and bait. The size frequency of the lobsters collected was converted to age-frequency data from an estimated growth curve (Polovina and Moffitt 1989), and the CPUE was computed for each age class (Fig. 3A and 3B). Sampling was conducted during the summers of 1986-88 and 1990. At Necker Island during 1986-88, CPUE was highest for 3-yr-olds, the age at which lobsters reach the minimum harvestable tail width size. In 1990, the CPUE for 3-yr-olds was substantially lower than in earlier years and lower than the CPUE for 2-yr-olds (Fig. 3A). This change is attributed to the heavy fishing pressure at Necker Island in 1989-90 (Fig. 1). The high CPUE for 2-yr-olds indicates that recruitment to the fishery is still good. At Maro Reef, the 1990 CPUE of all trappable age classes was very low (Fig. 3B). Since fishing effort at Maro Reef was relatively low in 1989-90, the 1990 age-frequency provides evidence that recruitment to the fishery was very low at Maro Reef in late 1989 through June 1990. Tail weight-frequency data from commercial vessels at Necker Island and Maro Reef for 1989-90 show results similar to the research data (Fig. 4A and 4B). Again, CPUE at Necker Island declined for most tail size classes from August 1989 to June 1990, but the persistence in the abundance of the 4-6-oz tails indicates that although the population has been reduced because of heavy fishing, recruitment to the fishery is still good. The CPUE of all tail-weight classes at Maro Reef declined substantially in 1989-90. Given the relatively light fishing effort at Maro Reef during this period, the decline in the CPUE of 4- to 6- and 6- to 8-oz tails is consistent with low recruitment. Low CPUE at Maro Reef through the end of 1990 indicates that recruitment to the fishery remained low all year. Other banks north of Maro Reef also have experienced very poor recruitment to the harvestable population, suggesting that the recruitment failure was the result of an oceanographic event impacting the northwestern portion of the archipelago.

While the reason for the low recruitment to banks in the northwestern portion of the archipelago is not known, an interesting correlation is observed between sea surface temperature from a NOAA buoy near Nihoa Bank and the ratio of spiny lobster landings from Maro Reef to Necker Island four years later (Fig. 5). Perhaps an unusually strong movement of cold water from the northwest transports larvae along the chain from west to east. This shift in larval abundance would appear as a drop in recruitment to the fishery for years later at Maro Reef and a corresponding increase in recruitment to the fishery at Necker Island.

SPAWNING STOCK BIOMASS

The spawning potential ratio (SPR), based on the spawning stock biomass per recruit approach, is used as the measure of reproductive potential in amendment 6 to the Crustacean Fishery Management Plan. This amendment defines the lobster population to be recruitment overfished when SPR is less than or equal to 0.20. Given the parameter estimates of M = 0.7/yr, and K = 0.3/yr, fishing effort of 1.18 million trap-hauls in 1990 results in an SPR of 0.40. This estimate is based on fishing effort and indicates that the current level of fishing may not be excessive in a year with average recruitment to the fishery. The SPR approach does not consider the current CPUE which reflects recruitment variation.

An index of the spawning stock biomass based on CPUE (kg/trap-haul), can be estimated from the research sampling at Necker Island and Maro Reef (Table 2). The ratio of this 1990 to 1977 index is an estimate of the current spawning population relative to the pre-exploitation spawning population. This ratio is 0.27 at Necker Island and 0.17 at Maro Reef, for an average of 0.22.

The difference between the two approaches and their results is important. The SPR approach says that 1.2 million trap-hauls will not, on average, result in recruitment overfishing. This approach does not address year to year variation. The CPUE approach indicates that the spawning biomass has been reduced by low recruitment to a level that might result in continued low recruitment.

Given the low level of the CPUE index and the fact that recruitment to the fishery from the 1990 spawning biomass will not be observed until 1993, it is prudent to reduce fishing effort in 1991 to permit the recovery of the population. Given the current low level of spawning biomass, it also would be prudent to protect the spawners before and during spawning. A closure of the fishery from January through August 1991 would afford such protection.

The Fox and CPUE models are used to estimate the 1991 CPUE from 1990 catch and effort as a function of 1991 effort based on the important assumption that 1991 is an average year with regard to the level of recruitment to the fishery (Fig. 6). The CPUE model predicts more rapid recovery than the Fox model. It is estimated that an annual effort of 400,000 trap hauls would result in a 1991 CPUE in the range of 0.9 (Fox dynamic model) to 1.0 (CPUE model) (Fig. 6). It is important to note that as of November 1990 recruitment to the fishery at Maro Reef and other northwestern banks had not improved. If Necker Island and Gardner Pinnacles represent the main sources for recruitment to the fishery, a limit for total fishing effort of 200,000 trap-hauls is advised. Since there is no evidence from catch and effort data through 1990 supporting a return to normal recruitment to the fishery at Maro Reef, it would be prudent to limit the 1991 fishing effort to ≤200,000 trap-hauls, which could be raised to 400,000 trap-hauls should a research cruise planned for June 1991 find good recruitment to the fishery at Maro Reef.

CITATIONS

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Table 1.--Annual landings of spiny and slipper lobsters (in 1000's), trapping effort (in 1,000's trap-hauls), and the percentage of lobster in the landings, 1983-90[a].

Year	Spiny lobster	Slipper lobster[b]	Total lobsters	Trapping effort	CPUE	Percent spiny lobster
1983[c]	158	18	176	64	2.75	0.90
1984	677	207	884	371	2.38	0.78
1985	1,022	900	1,902	1,041	1.83	0.57
1986	843	851	1,694	1,293	1.31	0.54
1987	393	352	745	806	0.92	0.57
1988	888	174	1,062	840	1.26	0.84
1989	944	222	1,166	1,069	1.09	0.81
1990	591	187	777	1,182	0.66	0.76

[a]Data are provided to the National Marine Fisheries Service as required by the Crustacean Fishery Management Plan of the Western Pacific Regional Fishery Management Council and are compiled by the Fishery Management Research Program, Honolulu Laboratory.

[b]Slipper lobster landings for 1989-87 are 72% of those reported, so they are comparable to landings subsequent to 1987 when a minimum size allowed the retention of about 73% of the catch.

[c]April-December 1983.

Table 2.--An index of female spawning stock biomass (kilogram/ trap-night) for spiny lobster.

	Index by year					
Location	1977	1986	1987	1988	1990	1990/1977
Necker Island	2.45	0.86	0.83	1.24	0.65	0.27
Maro Reef	2.14	1.26	1.74	1.71	0.36	0.17

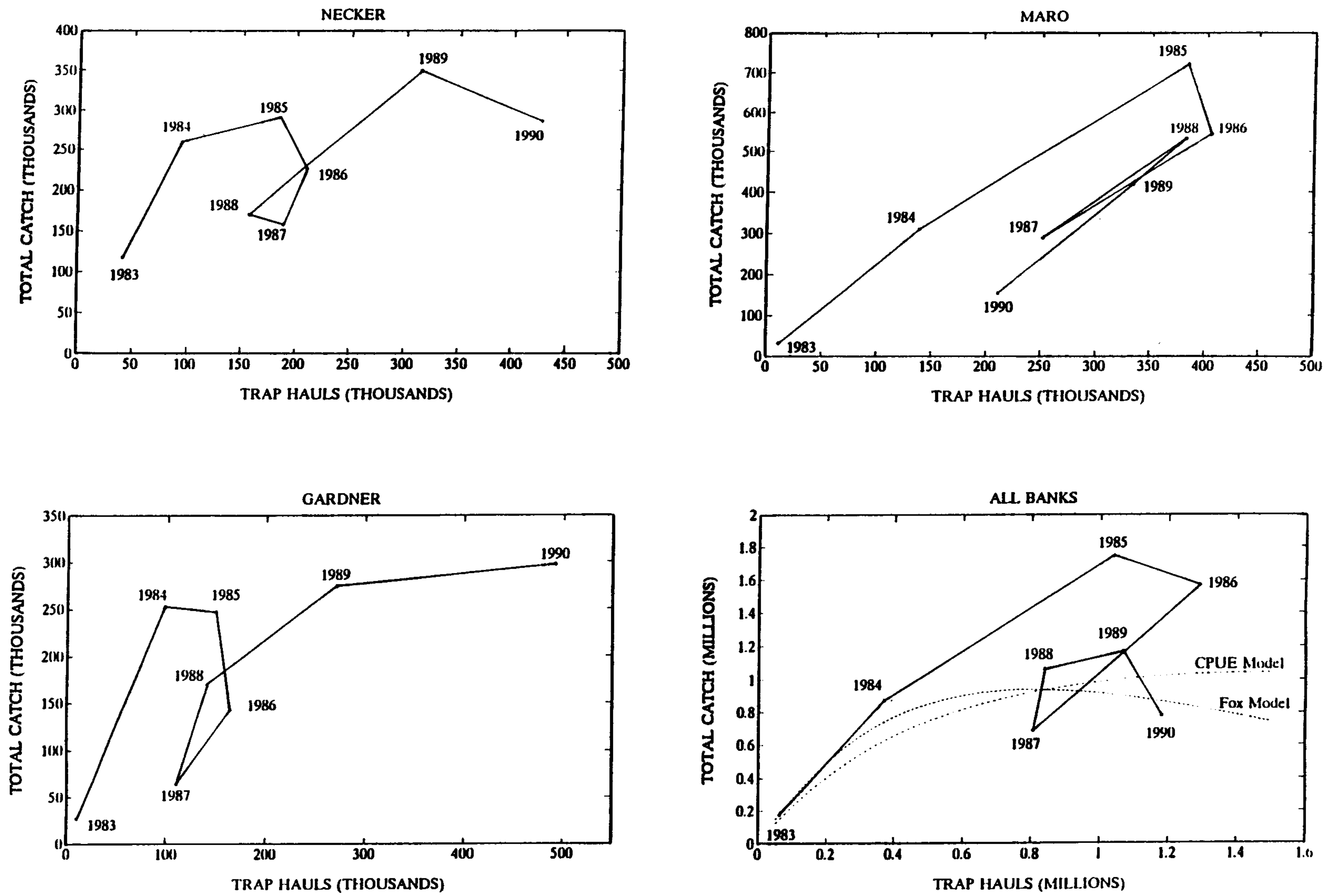

Figure 1.--Catch and effort, based on commercial logbooks, for spiny and slipper lobsters from Necker Island, Gardner Pinnacles, Maro Reef, all Northwestern Hawaiian Islands banks combined, 1983-90. Equilibrium catch and effort curves for the Fox production model and the catch per unit effort (CPUE) model are shown with the catch and effort for all banks.

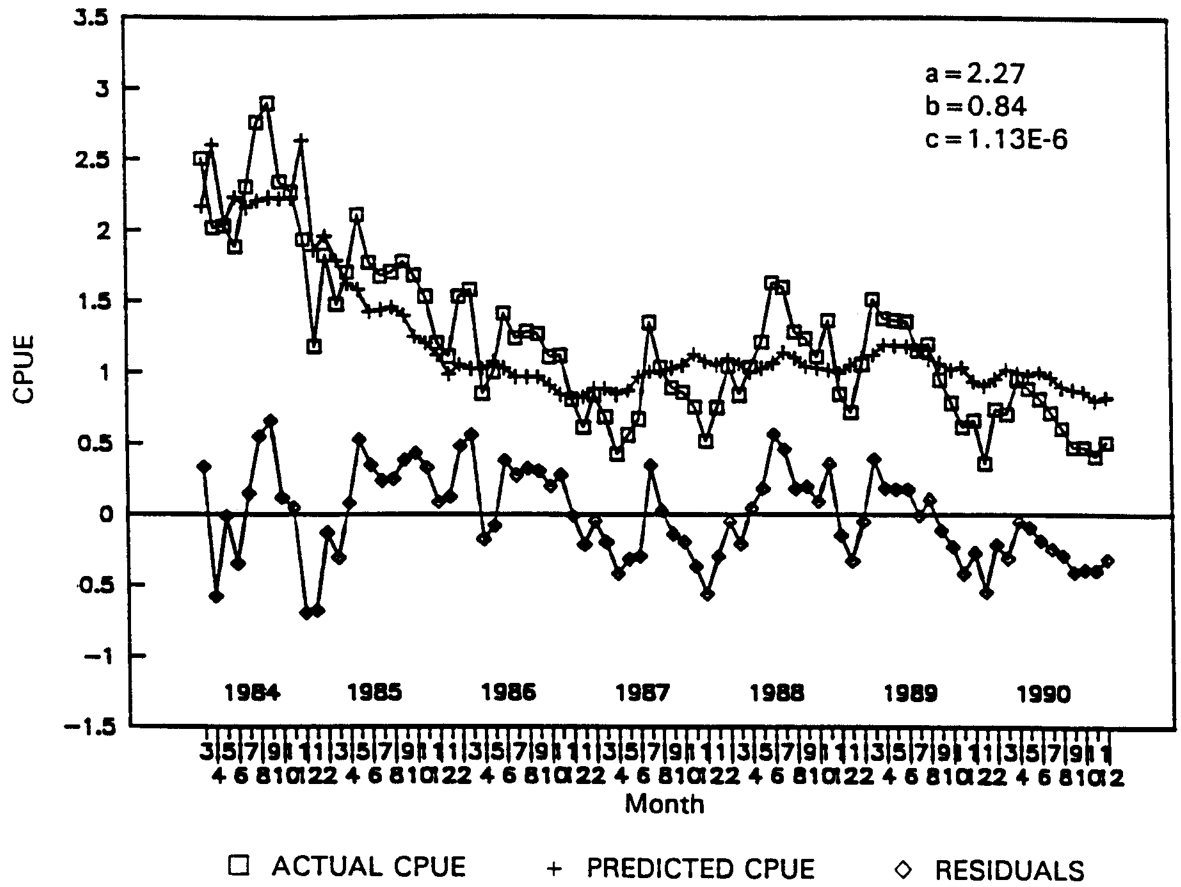

Figure 2.--Monthly catch per unit effort (CPUE) and fit of CPUE model for spiny and slipper lobsters based on commercial logbooks, for all Northwestern Hawaiian Island banks, 1984-90. The residuals are the differences between the actual and predicted CPUE values.

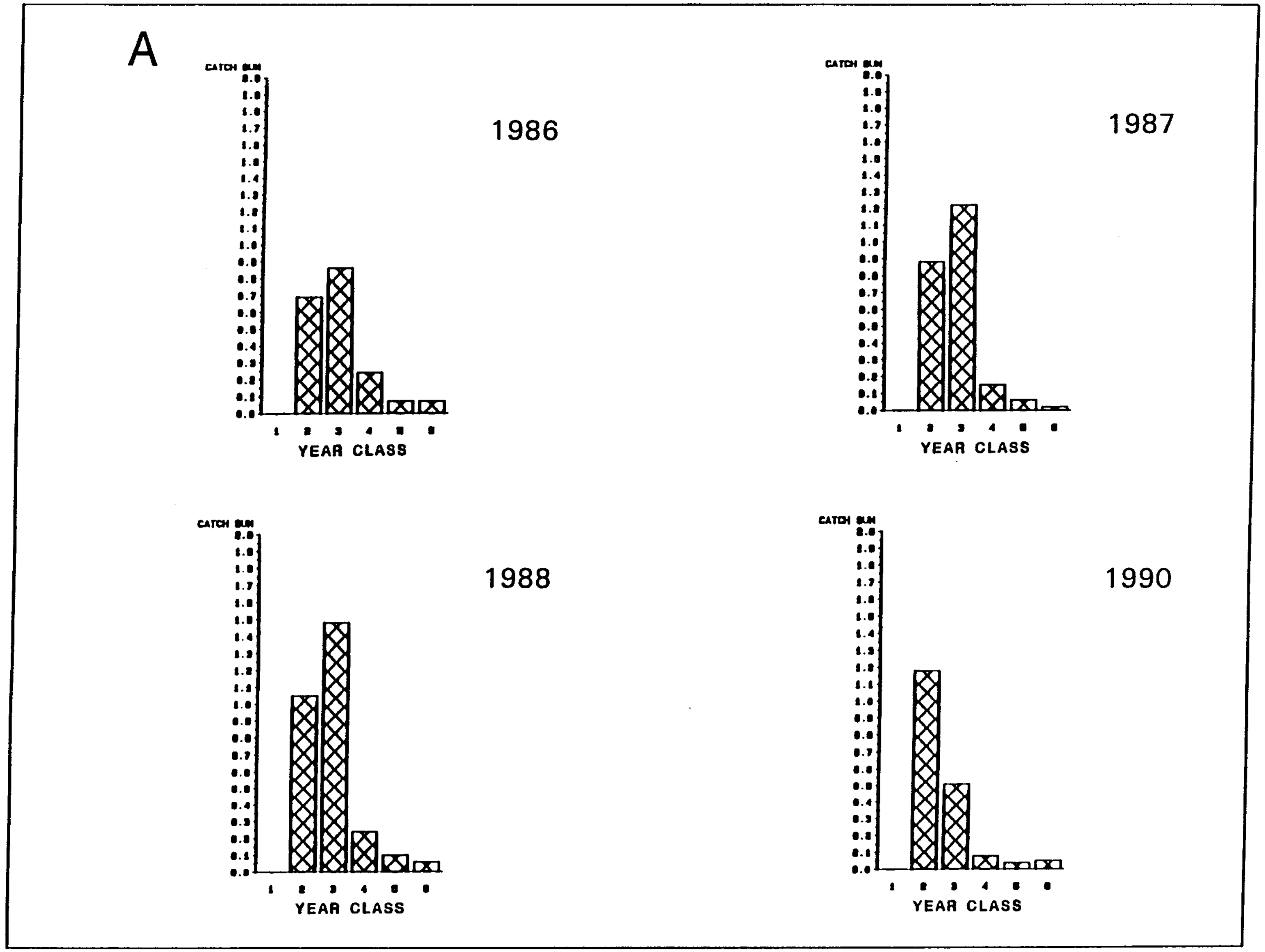

Figure 3.--Age-frequency distributions of spiny lobster, based on research sampling 1986-88 and 1990. (A) Necker Island.

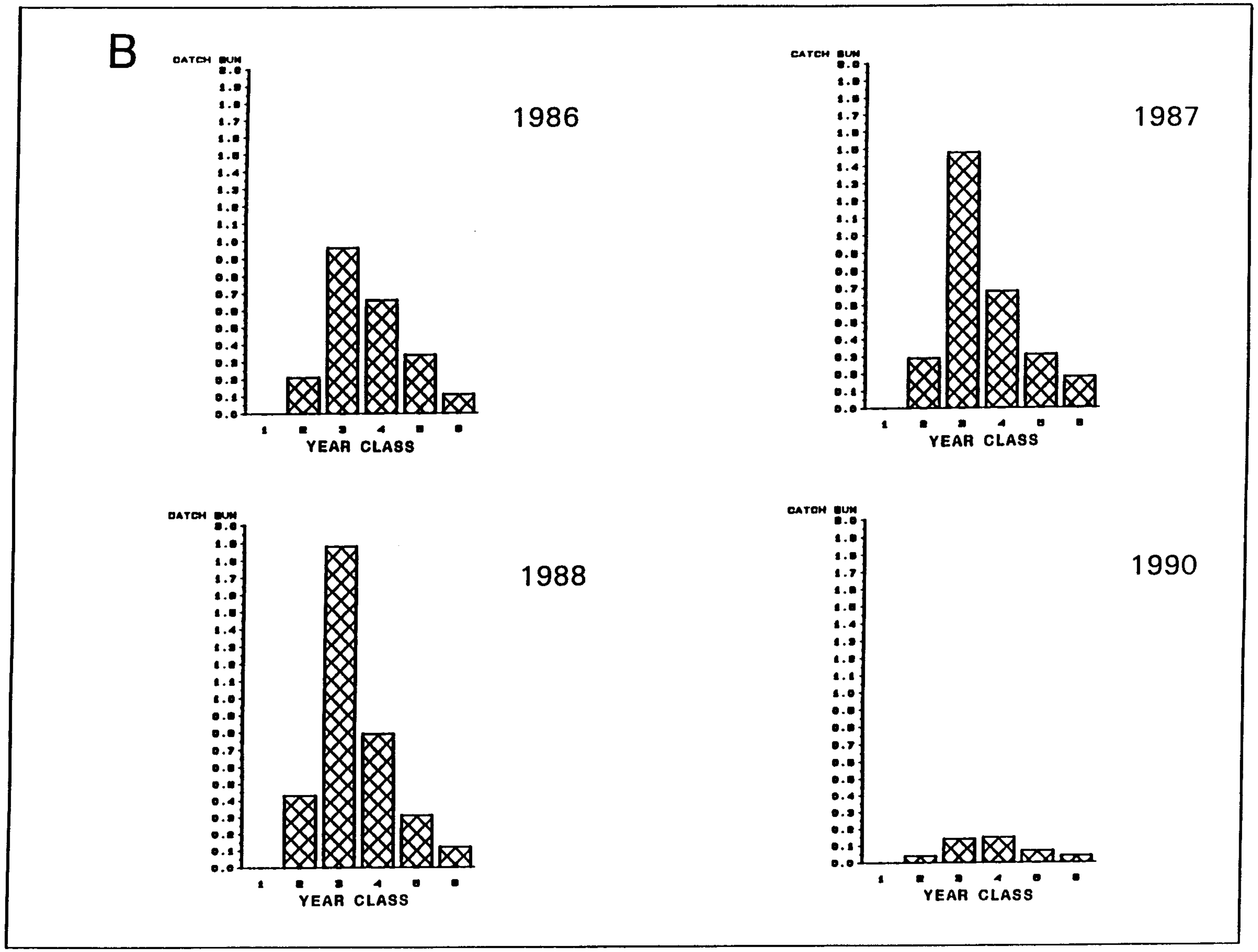

Figure 3.--Continued. (B) Maro Reef

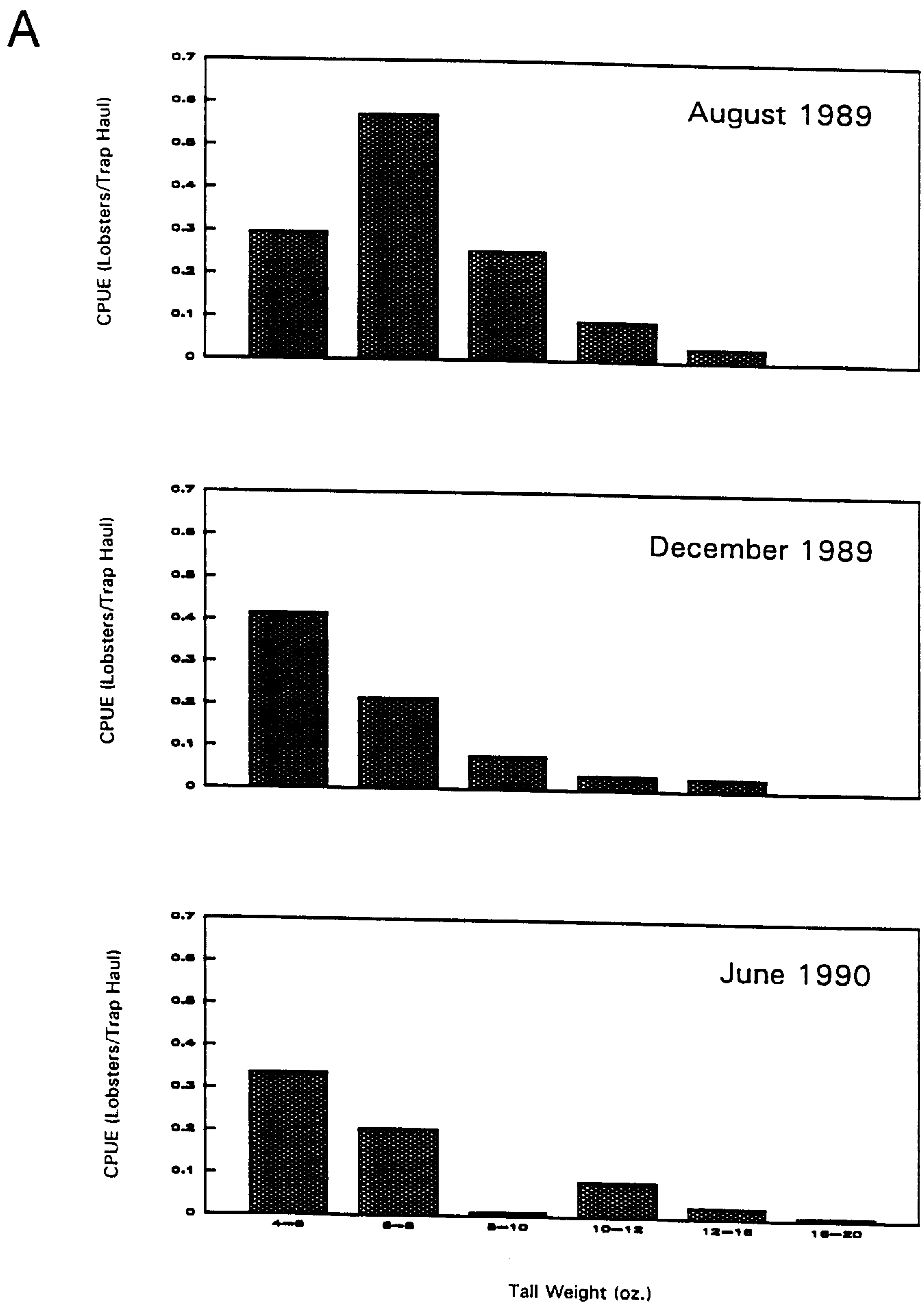

Figure 4.--Tail weight-frequency distributions from commercial vessels 1989-90. (A) Necker Island.

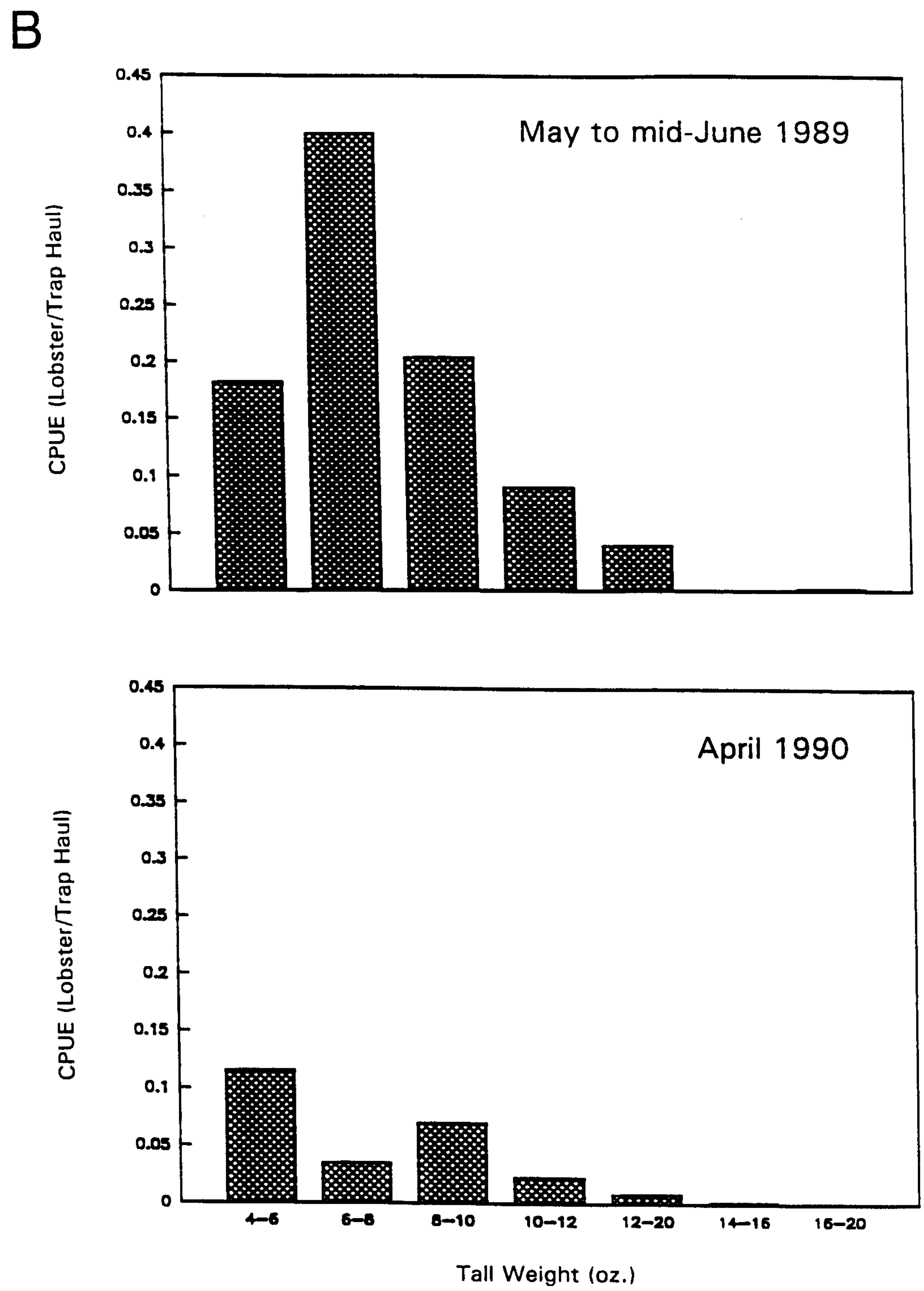

Figure 4.--Continued. (B) Maro Reef.

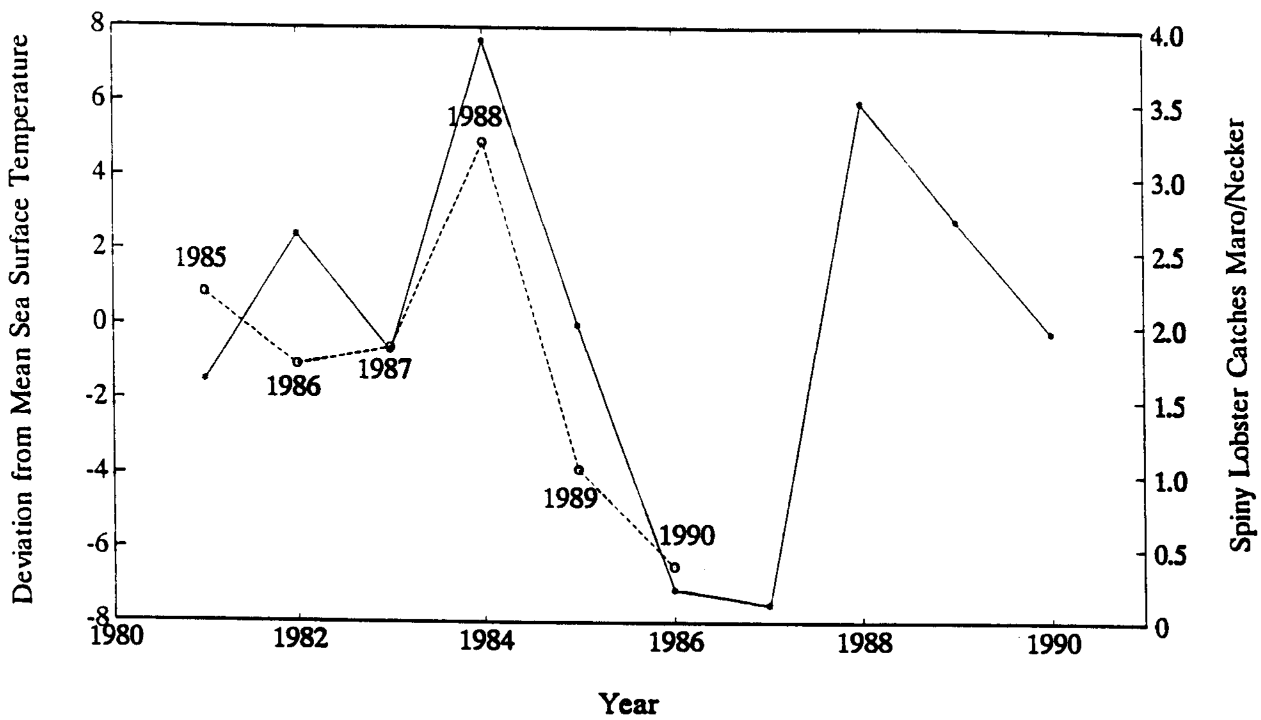

Figure 5.--Annual sea surface temperature anomaly and ratio of spiny lobster catches at Maro Reef to spiny lobster catches at Necker Island lagged 4 years. Broken line indicates spiny lobster catches Maro/Necker; solid line indicates deviation from mean sea surface temperature.

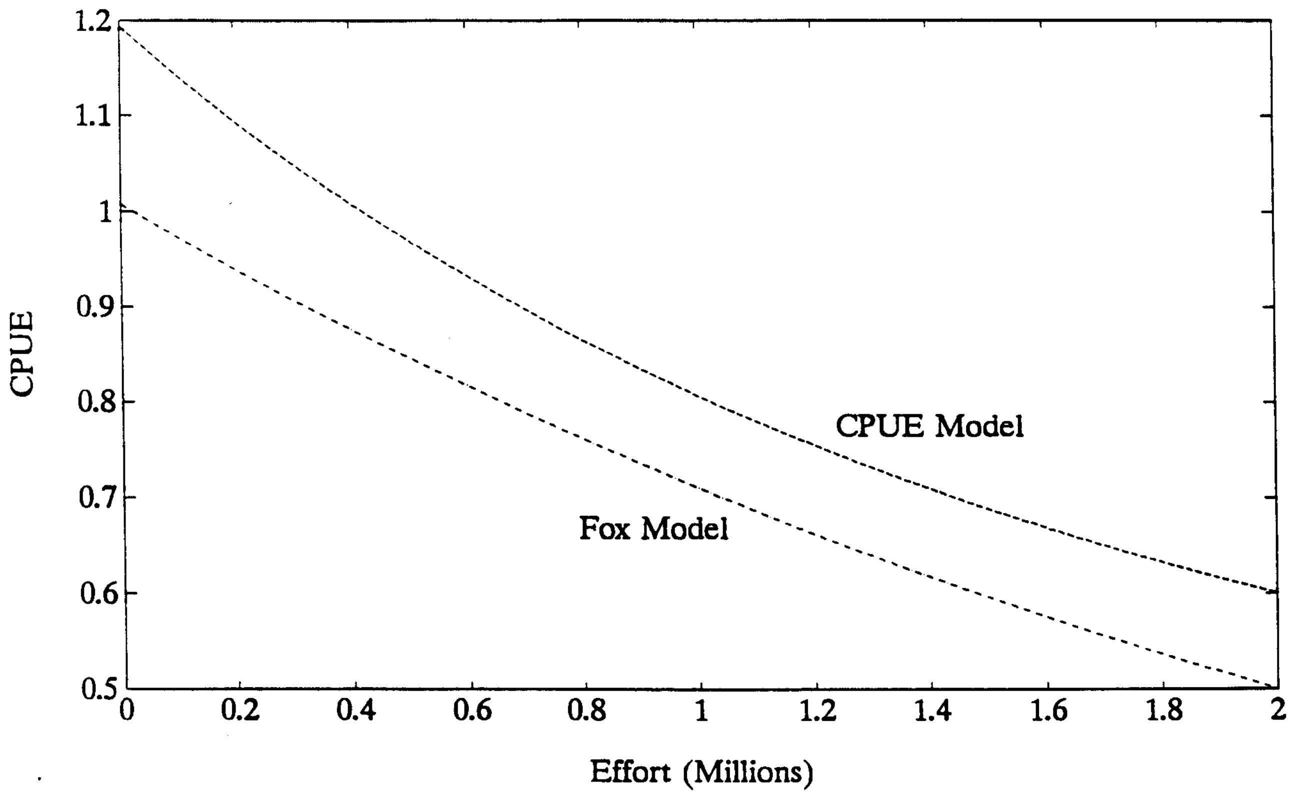

Figure 6.--Forecast of 1991 annual catch per unit effort (CPUE) as a function of 1991 fishing effort from the CPUE and Fox dynamic models, based on 1990 CPUE and fishing effort.